AFCRL-68-0622

BALLUTE DEVELOPMENT FOR LOKI-DART AND ARCAS ROCKETSONDES

AD 681455

John J. Graham, Jr.

Goodyear Aerospace Corporation
Akron, Ohio 44315

Contract AF19(628)-5851

Project 6682

Task 668208

FINAL REPORT

Period Covered: February 1966 to August 1968

November 1968

Contract Monitor: John B. Wright
Aerospace Instrumentation Laboratory

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Prepared
for

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE
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FOREWORD

The development work described in this report was conducted under Contract AF19(628)5851, Project 6682, Task 668208 by Goodyear Aerospace Corporation, 1210 Massillon Road, Akron, Ohio 44315. The contractor's report number is GER-14010. The contract monitor for this program was John B. Wright, Aerospace Instrumentation Laboratory, Air Force Cambridge Research Laboratories, Bedford, Massachusetts 01730. The work for this final report was carried out between February 1966 and August 1968. The author, John J. Graham Jr., submitted the manuscript in November 1968.

This technical report has been reviewed and is approved.

ABSTRACT

Goodyear Aerospace Corporation completed a program to develop a stabilizing decelerator for the Arcas and Loki-Dart meteorological rocketsondes. During the program of cyclic modification, test, and evaluation, 53 development units were flight tested at the Air Force Eastern Test Range. The design performance goals were reached for both systems. Fifty-five preproduction units of the Loki-Dart BALLUTE[a] were fabricated for further evaluation by Air Force Cambridge Research Laboratories. As a result of this program the Loki-Dart BALLUTE (Parachute, Meteorological A/B28U-5) was incorporated in the standardized PWN-8B Meteorological Rocketsonde currently in production.

[a]TM, Goodyear Aerospace Corporation, Akron, Ohio.

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SECTION I - INTRODUCTION

Goodyear Aerospace Corporation (GAC) completed the BALLUTE[a] development program for the Arcasonde and Dartsonde meteorological sounding systems under Contract AF19(628)-5851 for the Aerospace Instrumentation Laboratory of the Air Force Cambridge Research Laboratories (AFCRL), Office of Aerospace Research. The technical monitor was John B. Wright of the Vertical Sounding Techniques Branch of the Laboratory.

This program is the second phase of the development of a deployable stabilizing decelerator for the Arcas meteorological sounding system that was reported in AFCRL-65-877, Development of BALLUTE for Retardation of Arcas Rocketsondes. That program has been expanded to include the development of a similar BALLUTE for the Loki-Dart/Judi-Dart meteorological systems. This program in combination with the Phase-I effort completed by Goodyear Aerospace under Contract AF19(628)-4194 constitutes the first major concerted effort to develop a stable platform for rocket-launched, high-altitude, free-falling atmospheric probes.

The mission of both the Arcas and Dart systems is identical - obtain temperature and wind data in the atmosphere above 80,000 ft. Both systems are launched at near vertical angles with solid propellant rockets with a current maximum apogee altitude of about 220,000 ft. The 4-1/2-lb Arcasonde 1-A payload is separated from the 4.5-in.-diameter Arcas rocket at apogee where the BALLUTE is deployed. The Dart system separates from the 3-in.-diameter Loki or Judi motor at burnout and coasts to apogee where the 3/4-lb solid state instrument is ejected and descends on the inflated BALLUTE. Both systems are skin tracked by radar to provide a time-position history of the descent profile that is the basis for wind determination. Atmospheric temperature is detected by one of several varieties of thermistors and transmitted to the GMD ground station.

The need for a decelerator that was more sophisticated than a parachute is reflected in the design considerations of the program that were established to eliminate specific problems.

[a]TM, Goodyear Aerospace Corporation, Akron, Ohio.

1. Reliability - The occurrence of "streamers" (failure or delay of a silk parachute to open) had been too frequent.
2. Stability - Severe coning or oscillation of the silk parachute, especially at the higher altitudes, reduced the efficiency of the system in following the wind and caused a loss of the data signal at the ground station due to the variation of the transmitting antenna pattern.
3. Descent rate - The accuracy with which a falling body is laterally displaced by winds is a function of the fall rate. The slower the fall rate, the less lag occurs in the response of the system, hence the greater its accuracy as a wind sensor. Aerodynamic heating of the thermistor, although a relatively minor factor, results in erroneous temperature data. Any reduction of the descent velocity directly reduces this kind of error.
4. Reflectivity - To accurately determine both reference altitudes for the temperature data and the lateral excursions of the sonde system which define winds, the system must present a sufficiently large reflective surface throughout the mission so that it can be tracked by Mod -2 or -589 radar.
5. Production cost - Based upon current parachute costs, a goal of $200.00 per unit for the Arcas BALLUTE and $30.00 per unit for the Loki-Dart BALLUTE (both in quantities of 500 units) was established.

SECTION II - PROGRAM SCOPE

1. PROGRAM PLAN

Because the preliminary analysis and design for the Arcas BALLUTE was accomplished under the earlier contract, the main effort of this program was in product improvement of the Arcas system and adaptation of that technology to the Loki-Dart requirements. A program plan of modification test and evaluation in recurring cycles was to be the format for the development. Twenty-nine Arcas development units and 25 Dart systems were to be fabricated and tested. Fifty-five Dart BALLUTEs of the final configuration were to be fabricated for further evaluation by AFCRL.

The objectives of the program may be summarized by the following program plan that served as a guide.

1. Use the largest BALLUTE that can be economically packaged in the space currently available in each system.
2. Use the lightest gage material possible without compromising structural integrity.
3. Develop a BALLUTE geometry with the highest possible drag coefficient without sacrificing stability.
4. Minimize the number of film panels and seams for economical production.
5. Use commercially available hardware wherever possible and keep metalcraft fabrication to a minimum.
6. All assembly and manufacturing techniques should be compatible with economical high production tooling and fabrication aids.
7. Develop packaging procedures using state-of-the-art technology that can be converted to assembly line methods.

8. Provide a quality control program that ensures the maintenance of high quality workmanship and provides for periodic lot acceptance test procedures.

2. FABRICATION AND DOCUMENTATION

A total of 108 BALLUTE systems was fabricated during this program. Twenty-nine Arcas development units that incorporated 10 major configuration changes were built, flight tested, and evaluated. Twenty-five Dart BALLUTEs were tested similarly with nine major modifications. After finalization of the Dart configuration, 55 qualification units were delivered to AFCRL for further evaluation.

In addition to the hardware delivered under the contract, fabrication drawings, packaging specifications, and quality assurance plans for each of the final configurations were transmitted to AFCRL. In support of the development of both systems, continuing seaming techniques development and testing, inflation tests, airdock drop tests, and flight test data analysis were conducted.

3. RESULTS

a. Achievement

The success of this program should be evaluated in terms of the degree to which the contractually established design goals were attained. The design goals for both systems covered the same general areas of reliability, descent rate, stability, reflectivity, and production costs. With the exception of the production costs, the performance goals were either exceeded, met, or shown to be feasible.

b. Loki-Dart BALLUTE

(1) General

The Loki-Dart BALLUTE is the smaller of the two systems and generally was more successful than the Arcas system primarily because of its smaller size and less severe deployment environment.

(2) Reliability

The requirement that the system operate in 98 percent of the cases in

which it is deployed in the proper velocity-altitude envelope was to overcome the incomplete or belated inflation of the parachute system. Twenty-five Loki-Dart BALLUTEs of various configurations were flight tested. Seven of these tests were abortive due to separation system failure or premature ignition. One unit was deployed at an excessively high aerodynamic pressure because of the low apogee achieved by the Loki motor. Of the remaining 17 flights in which the test point was reached, 16 operated properly and one failed structurally. The unit that failed at deployment was attached to the instrument by a two-point bridle suspension system, which may have resulted in entanglement of the instrument and BALLUTE. If the test of this unit with an unusual suspension is eliminated from the flights to be evaluated for reliability, 16 of 16 Loki-Dart BALLUTEs performed satisfactorily.

In addition to the 25 development units tested, 55 Loki-Dart BALLUTEs of the final design configuration were fabricated for further evaluation by AFCRL.

Although this contract does not include Goodyear Aerospace participation in testing or evaluating these units, the general results of the performance of the BALLUTEs were transmitted to Goodyear Aerospace. One problem area was noted that would have an effect on reliability. A number of BALLUTEs that had been stored for several months were removed from their containers and examined. In certain areas the adhesive of the pressure sensitive meridian straps had been forced out along the edge of the tapes causing the adjacent film to adhere to it. If this sticking of the film were strong enough, the BALLUTE could be torn on deployment. A design change replacing these tapes with a heat-sealable meridian strap was initiated to eliminate the problem.

(3) Stability

The stability goal under equilibrium descent conditions for both the Arcas and Loki-Dart systems was ±3 deg. The purpose of the stability requirement is twofold: to maintain a stable antenna pattern and to avoid wind errors due to lift on the system. Unfortunately the methods of determining stability or instability to this degree under actual flight conditions have been less than adequate.

Motion pictures taken with long-range cameras at the Air Force Eastern Test Range (AFETR) have provided the most usable data for measuring stability. Fewer Loki-Dart flights were successfully photographed than Arcas flights. Because the Arcas BALLUTE is 15-ft in diameter while the Loki-Dart BALLUTE is 7 ft in diameter, the shape and motion of the Arcas BALLUTE was more easily defined. In neither system was the photographic resolution such that the meteorological instrument was distinguishable. In the final configuration as well as in some of the earlier configurations, the BALLUTE geometry and therefore its aerodynamic characteristics were identical except for size, thus permitting valid extrapolation of stability characteristics from one to the other.

A preliminary comparison of BALLUTE stability versus parachute stability with photographic data should be made to emphasize the need for the stability requirement and to define the order of magnitude of the problem. Two films of apparently typical Arcasonde tests at altitudes above 100,000 ft showed the parachute systems in a nearly flat spin, coning about an included angle greater than 120 deg. In one of these films the system executed a 360-deg loop more than once.

In at least three films of Arcas BALLUTE flights at comparable altitudes where the BALLUTE shape was clearly defined, the degree of coning, if present, was too small to be measured. Less extensive documentation of Loki-Dart BALLUTE tests confirmed in part by airdock drop tests show the same high degree of aerodynamic stability.

Although a stable BALLUTE solved the wind-error portion of the stability requirement, it does not necessarily follow that the instrument and therefore the sensing thermistor and the data transmission antenna are also stable. Determination of the stability of the suspended instrument has been based largely on the quality of the signal received by the GMD ground station, specifically with respect to the absence or presence of signal dropout.

In 10 of 18 Loki-Dart BALLUTE flights, no signal dropouts occurred. The remaining eight flights resulted in signal dropouts occurring in varying degrees. In one of these flights the system drifted toward the ground station, resulting in high elevation angles of the GMD tracking antenna.

In such cases the tracking dish sees that portion of the signal transmitted in the near-vertical direction from the instrument above. The Dart instrument employs a vertically oriented monopole transmitting antenna with maximum output in the horizontal plane decaying to a null at the vertical axis. Whenever the strength of the received signal drops below the noise level of the system, the temperature data no longer can be detected and this condition constitutes what is termed a "signal dropout."

In the eight Dart flights where signal dropout occurred, the intensity ranged from a very few spikes in the total 24-min sounding to moderate groups over a period of several minutes. In no case was continuous temperature data affected. All attempts to associate the presence of signal dropouts with some identifiable causal phenomenon have failed. The evidence of the almost perfectly stable BALLUTE and the lack of a cyclic pattern that might be associated with a pendulum motion of the instrument seem to indicate a signal dropout cause other than physical instability.

(4) Descent Rate

The contract established a goal for the falling velocity of the system by the words "as slowly as possible." It further defined a minimum ballistic coefficient of $W/C_D A = 0.05$. After initial successes of the Loki-Dart BALLUTE and in conjunction with an expansion of the test program this goal was changed to $W/C_D A = 0.03$ for even slower fall rates. Since slower fall rates greatly enhance the validity of both temperature and wind data, the successful attainment of this goal by the Loki-Dart BALLUTE has resulted in a general upgrading of the rocketsonde system not originally contemplated.

(5) Reflectivity

Compatibility with the tracking radar is essential for the calculation of the winds and for the establishment of the altitude base for the temperature data. The contract requires that the BALLUTE be sufficiently reflective to present an adequate target for those types of radar normally used for meteorological rocketsonde missions. By vacuum deposition of aluminum on portions of the Mylar film of the BALLUTE, such a reflective surface was provided. A variety of patterns were tried as the

BALLUTE geometry evolved and configuration changes were tested. All of the configurations were tracked without problems and this design goal was easily achieved.

(6) Production Cost

Since the performance goals were established as the result of the shortcomings experienced with the silk parachute retardation device, it follows logically that cost goals should be similarly established. At the outset of the program the current cost of the silk parachute for the Loki-Dart rocketsonde was about $30.00, which was the target price set forth in the contract for the BALLUTE in quantities of 500. Although considerable effort was devoted to minimizing the number of gores and simplification of components as well as development of economic fabrication techniques, the projected cost per unit is $125. Obviously the production cost target was not achieved. A tradeoff analysis between improved performance and fewer abortive missions on the one hand and increased cost on the other must be made by others.

The development of the Loki-Dart BALLUTE identified in its final configuration as "Parachute, Meteorological A/B28U-5" has been a successful effort as evidenced by the standardization of this BALLUTE as a component of the PWN-8B rocketsonde system currently in production.

c. Arcas BALLUTE

(1) General

Much of what has been said about the Loki-Dart goals applies to the Arcas system as well. In general, the Arcas BALLUTE development progressed more slowly than the Dart program and the performance characteristics were overshadowed by the impressive record of the Loki-Dart.

The main problem encountered was the conflict between the available packaging volume and the size of the BALLUTE required to achieve the proper descent rate. Many of the early configurations tested were devoted to an attempt to build a BALLUTE of less than 1/2-mil-thick Mylar that was reinforced in areas of higher stress and that would be large enough and still packageable.

Eventually experimentation with thinner films was abandoned and the

main effort was directed toward more efficient aerodynamic drag geometry and better packaging techniques. The final Arcas configuration evolving from the program was a 15-ft-square BALLUTE that embodied solutions to the structural problems encountered on other configurations and that yielded a sufficiently slow fall rate and stability.

The final Arcas configuration was tested only once because it was the last of the development units. Funds were not available for fabrication of additional units for further evaluation. Because so many major modifications were tried during this effort, evaluation of the program in terms of design goal achievement becomes more difficult and requires some interpretation.

(2) Reliability

The design goal for the reliability of the Arcas BALLUTE was exactly the same as that for the Loki-Dart - 98 percent. Reliability of the BALLUTE is essentially related to its ability to withstand deployment dynamic loads. Since the early tests were devoted to testing thin films, these cannot be used validly in reliability statistics. Similarly, each subsequent modification contained solutions to previously encountered problems and only the final configuration is worthy of evaluation with respect to any of the design goals.

(3) Stability

The stability of the Arcas BALLUTE has been documented on film and was discussed earlier in the review of the Loki-Dart BALLUTE. The stability of the Arcasonde instrument beneath the BALLUTE is subject to the same conjecture as for the Dart.

(4) Descent Rate

The last Arcas configuration showed a $W/C_DA = 0.045$, which is within the specified goal.

(5) Reflectivity

As in the Loki-Dart system no tracking problems were ever encountered, indicating adequate reflectivity.

(6) Production Cost

The cost goal for the Arcas BALLUTE, like the Dart, was based on current parachute costs. The Arcas BALLUTE has been estimated at \$250.00 per unit in lots of 500 as compared to the target price of \$200.00 per unit. In view of a 20-percent increase in production costs at Goodyear Aerospace between the time the goal was established and the present, this goal was more nearly achieved than the Loki-Dart cost target. A complete evaluation of the Arcas BALLUTE (identified as "Parachute, Meteorological A/B28U-1") should be postponed until additional tests of the final configuration can be conducted.

SECTION III - ARCASONDE BALLUTE DEVELOPMENT PROGRAM

1. AREAS OF INVESTIGATION

The primary purpose of the Arcasonde BALLUTE development program was to improve the performance of the Arcasonde 1-A sounding system to the degree that the improvement of the stabilizing decelerator system would allow. This sounding system currently is still the standard system used to obtain high-altitude soundings for the meteorological rocket network.

Both the feasibility and practicability of the BALLUTE for this mission have been previously demonstrated during the program conducted by Goodyear Aerospace under Contract AF19(628)-4194. The details of this effort are reported in AFCRL-65-877 (GER-12317), Development of BALLUTE for Retardation of Arcas Rocketsondes, December, 1965.

In the statement of work for this second phase of the development, the contract specifies that the results of the earlier program be the basis for the BALLUTE configuration and that emphasis be placed on improvements to that configuration. In addition to the design goals of reliability, stability descent rate, reflectivity, and cost, the contract specifies the following (but not limiting) areas of investigation:

1. BALLUTE film material and thickness
2. BALLUTE size
3. Meridian suspension system
4. Inlet springs and interface
5. Swivel assembly requirements
6. Residual air bleedoff system
7. Thermal protection from separation charge
8. Separation charge diversion system
9. Tooling and fabrication techniques

2. DESIGN GOALS

a. General

Some discussion of two of the design goals (reliability and stability),

the reasons for their inclusion in the contract, and their respective relative importance will provide a better understanding of the emphasis placed on these two areas of the configuration.

b. Reliability

The basic reasons for any reliability requirement are obvious and need no additional elaboration here. However, reliability in the light of an atmospheric sounding mission and how it affects expendable hardware does reflect additional specific implications.

High-altitude meteorological soundings may be categorized in two major divisions. The larger mission group consists of a regularly scheduled program of soundings that are most meaningful when the data are obtained at the same hour of the day. An aborted mission results in an interruption of the regularity of the data pattern, causing some deterioration in its value and dissemination. Because of the quantity of soundings required annually to support such a program, a low performance reliability (that is, a high failure rate), becomes most costly.

The smaller group of sounding missions may be termed special, that is, the standard data are obtained but primarily for a specific purpose such as in support of a major aerospace mission. Failure under such circumstances can cause costly countdown holds or results in execution of a launch with less information than desirable about the upper atmosphere.

c. Stability

The aerodynamic stability of the descending sonde has a direct effect on the accuracy and validity of the temperature and wind data. The upper air streams are determined by the lateral excusions of the sonde. If the system is not stable because random or regular lift forces are imparted to the system, the motion of the sonde deviates from the motion of the surrounding air mass (wind) in proportion to the magnitude of the lift force.

The temperature sensor in the Arcasonde 1-A system is a bead thermistor. Although the bead is coated to reduce the effects of radiant heating, there is considerable evidence of temperature variation due to alternate period of exposure to and shielding from solar radiation. Obviously, aerodynamic instability magnifies the effects of this phenomenon.

The last and perhaps the most significant effect of instability is the interruption of the reception of the transmitted data. Because the antenna pattern from the 1A sonde is not omnidirectional, excessive tilting of the instrument or high elevation angles will result in loss of signal or signal dropout.

One of the major efforts of this program has been to eliminate signal dropouts on the TMQ-5 temperature trace by stabilizing the BALLUTE and the instruments and, thereby, stabilizing the transmitting antenna. It has long been accepted that there exists a low energy output of signal in the area directly below the center of the antenna, and for this reason, signal dropout is expected when this null is presented to the GMD-II tracking dish. Furthermore, it has been correctly assumed that if the instrument is not stable during descent, the null may be seen randomly by the GMD-II, resulting in signal dropout. Consequently signal dropout had been generally used as an indicator of system stability.

During several flights, various Arcas BALLUTEs have been shown to be perfectly stable while the TMQ-5 record of the flight still contained considerable signal dropout. At this point the validity of signal dropout as a valid indication of stability was questioned. Signal transmission and its efficiency is not within the scope of the Goodyear Aerospace contract, but stability is. Therefore, an in-depth comparison was made of one specific flight in which a complete set of data including motion pictures was available to see what relationships, if any, could be found between the position and motion of the BALLUTE and the meteorological data. This flight test was conducted at AFETR on 18 December 1967.

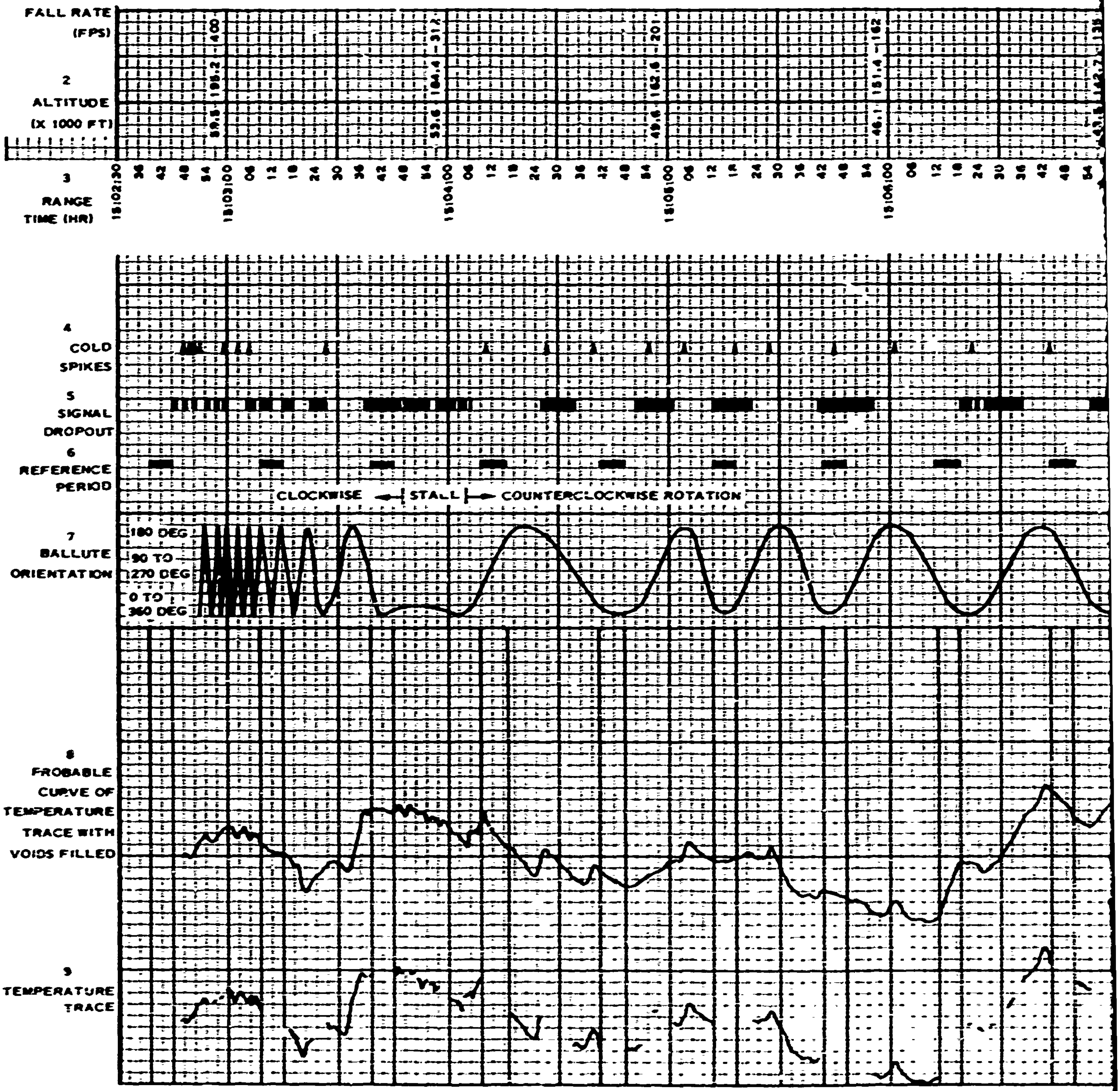
All available data have been combined and plotted against a time base and are shown in Figure 1. The method of obtaining each line of data is as follows:

1. Line 1: fall rate (fps) - The velocities noted at the reference range time were computed from radar data by UDRI.
2. Line 2: altitude (kilometers) - Same as line 1.
3. Line 3: range time (sec) - Basically, this time scale is that of the TMQ-5 record with motion picture and radar-generated data scaled to match.

4. Line 4: cold spikes (peak location) - These points are a direct projection of the "spikes" of Line 8.
5. Line 5: signal dropout (occurrence and duration) - These time spans are a direct projection of signal dropout from the original trace including dropouts occurring during reference periods.
6. Line 6: reference periods - These time increments represent the periods when a reference calibration signal is being transmitted instead of temperature data.
7. Line 7: BALLUTE orientation-rotational altitude (deg) - This data was obtained from motion picture film with a range-time coding on its margin. The zero reference point was chosen randomly as the alignment of one side of the square BALLUTE with an axis of the photographic frame. The 0-, 90-, and 180-deg positions were plotted against time, and the remainder of the (sine wave) was faired in.
8. Line 8: temperature trace (voids extrapolated) - This curve represents a meticulously executed full-scale trace of the original TMQ-5 record. In those areas of reference or signal dropout, the temperature curve has been extrapolated based upon the temperature level and trend at the beginning and end of the data gap so as to represent the true curve as if it were free of reference and dropout.
9. Line 9: temperature trace (valid portions only) - In order to show which portions of Line 8 have been filled in the actual "good data," this curve has been traced full scale.

Goodyear Aerospace observed that:

1. There is no apparent relation to signal dropout to altitude or fall rate
2. Cold spikes occur generally twice per system revolution


FALL RATE
(FPS)
2
ALTITUDE
(X 1000 FT)
3
RANGE
TIME (HR)
4
COLD
SPIKES
5
SIGNAL
DROPOUT
6
REFERENCE
PERIOD
CLOCKWISE STALL COUNTERCLOCKWISE ROTATION
7
BALLUTE
ORIENTATION
180 DEG
90 TO
270 DEG
0 TO
360 DEG
8
PROBABLE
CURVE OF
TEMPERATURE
TRACE WITH
VOIDS FILLED
9
TEMPERATURE
TRACE

A

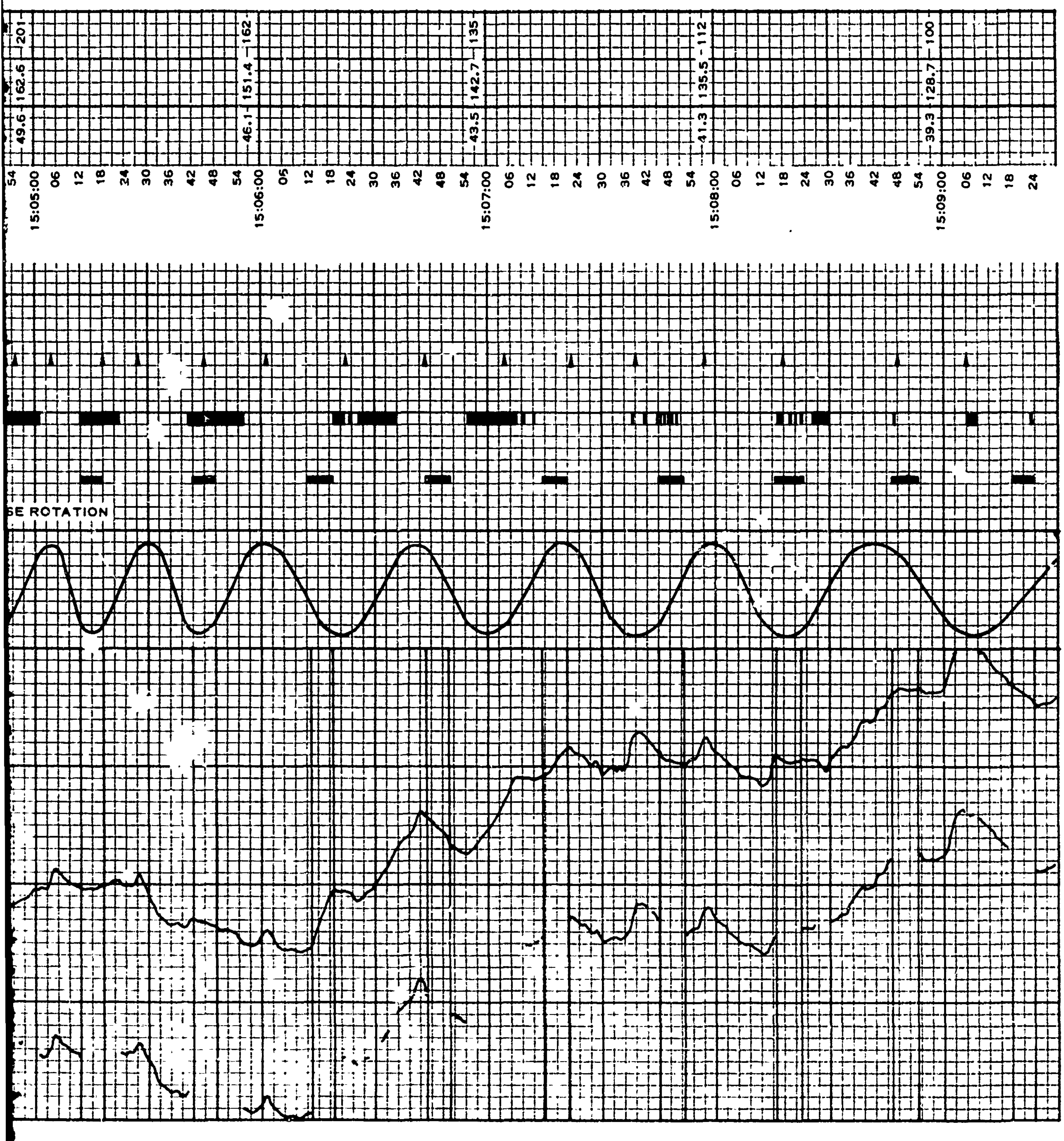


Figure 1 - Arcasonde Flight Data

B

3. Signal dropout groups appear generally once per system revolution
4. There is no apparent relationship between noted phenomena and clockwise or counterclockwise motion

Examination of instrument or antenna performance was not within the scope of Goodyear Aerospace's responsibility in this program. Only because signal dropout is used as a criterion of system instability was this analysis made and the following possible explanations of the phenomena observed as presented because they related to interpretation and evaluation of BALLUTE performance.

1. The cold spikes that occur twice per BALLUTE revolution may be attributed to shadowing of the thermistor bead from solar radiation by the two thermistor mount posts.
2. The occurrence of signal dropout once per BALLUTE revolution may be due to the alignment of the feed point null of the Arcasonde 1-A antenna with the ground station.

3. ARCASONDE FLIGHT TEST SUMMARY

a. General

Although both the details of each configuration tested and the test results are presented in Table I, this summary is intended to point out the significant design changes and the reasons.

b. Configuration A

The first pair of test items in this phase of the program, Units 1 and 2, were 16-ft-diameter hexagonal BALLUTEs constructed of 1/4-mil Mylar. Twelve meridian straps of 15-lb breaking strength braided nylon terminated at 12 beryllium copper leaf springs mounted as a swivelplate. The acquisition of multiple targets by tracking radar indicated breakup of the BALLUTE upon deployment. The 1/4-mil Mylar of the first two units probably failed to withstand the dynamics of separation. Flagging of the film prior to full inflation may have been the cause for the failure.

This period of flagging was reduced by increasing the inlet area, which in turn reduced the inflation time.

In the interest of developing the largest possible decelerator and also providing the slowest descent rate, it was decided to attack other possible problem areas first before going to heavier material. It had been shown in the earlier development effort that because of the large number of unknown factors, strictly analytical compilation of the forces acting on the BALLUTE during ejection and deployment was impractical. Therefore, each subsequent test configuration was modified only slightly, but in the most suspect area so as to permit empirical isolation of problem areas.

c. Configuration B

Units 3 and 4 incorporated the first configuration change. The only changes made were an increase of the inlet area from 86 to 300 sq in. with an accompanying change in the spring interface to accommodate the larger inlet. The results of the tests of both of these units were the same. No evidence of BALLUTE breakup was present, but in both cases the Arcasonde 1-A instrument separated from the BALLUTE immediately upon ejection. This breakup indicated that the 12- to 15-lb woven nylon straps attached to the six leaf springs were not strong enough.

d. Configuration C

The following changes were incorporated in the structural interface between the BALLUTE and instrument for Units 5 and 6.

1. The design of the sixth inlet erection spring was simplified.
2. Rubber grommets were added to the meridian attachment holes in the spring ends to prevent cutting of the nylon by the spring.
3. The strength of the braided nylon meridians was increased for 15- to 50-lb rated break strength.

Although these changes prevented instrument separation, the BALLUTE film again ruptured. At this point, the effort to maintain 1/4-mil Mylar film was abandoned.

TABLE I - ARCAS BALLUTE FLIGHT T

Unit no.	Test no.	Test date	Instrument	BALLUTE construction: Diam or width (ft)	Shape	Cone angle (deg)	Number gores	Film gage	Type seam	Burble fence size (percent)	Suspensio: Meridian No.	Meridian Type	Meridian Strength (lb)	Bridle no. lines
1	1604	4/20/66	1-A	16	Hex	80	12	1/4	Butt	12	12	NY	15	12
2	3242	4/22/66	1-A	16	Hex	80	12	1/4	Butt	12	12	NY	15	12
3	0539	5/23/66	1-A	16	Hex	80	12	1/4	Butt	12	12	NY	15	6
4	1709	5/25/66	1-A	16	Hex	80	12	1/4	Butt	12	12	NY	15	6
5	1053	7/7/66	1-A	16	Hex	80	12	1/4	Butt	12	12	NY	50	6
6	0715	7/8/66	1-A	16	Hex	80	12	1/4	Butt	12	12	NY	50	6
7	0851	7/27/66	1-A	14	Hex	80	12	1/3 & 1/2	Butt	12	12	NY	50	12
8	0785	7/29/66	1-A	14	Hex	80	12	1/3 & 1/2	Butt	12	12	NY	50	12
9	7391	8/15/66	1-A	12-1/2	Hex	80	12	1/2	Butt	12	12	NY	50	12
10	5554	8/16/66	1-A	14	Hex	80	12	1/2	Butt	12	12	NY	50	12
11	7867	8/18/66	1-A	14	Hex	80	12	1/2	Butt	12	12	NY	50	12
12	2641	9/14/66	DMQ-9	14	Hex	80	12	1/2	Butt	12	12	NY	50	12
13	3163	9/15/66	DMQ-9	14	Hex	80	12	1/2	Butt	12	12	NY	50	12
14	1947	9/19/66	1-A	15	Hex	80	12	1/2	Butt	12	12	NY	50	12
15	1731	9/20/66	1-A	15	Hex	80	12	1/2	Butt	12	12	NY	50	12
16	2577	1/30/67	1-A	15	Oct	102	8	1/2	Peel	20	8	NY	50	8
17	2694	1/31/67	1-A	15	Oct	102	8	1/2	Peel	20	8	NY	50	8
18	0776	3/1/67	1-A	15-1/2	Oct	102	8	1/2	Peel	20	8	NY	50	8
19	7092	3/2/67	1-A	15-1/2	Oct	102	8	1/2	Peel	20	8	PS	60	8
20	3605	4/12/67	1-A	15-1/2	Oct	102	8	1/2	Peel	20	8	NY	50	8
21	0793	4/19/67	1-A	15-1/2	Oct	102	8	1/2	Peel	20	8	PS	60	8
22	8990	5/10/67	1-A	15-1/2	Oct	102	8	1/2	Peel	20	8	PS	60	8
23	8622	5/10/67	1-A	15-1/2	Oct	102	8	1/2	Peel	20	8	PS	60	8
24	3187	7/6/67	1-A	15-1/2	Oct	102	8	1/2	Peel	20	8	PS	60	8
25	3069	8/16/67	1-A	15	Sq	102	4	1/2	Butt	20	4	PS	60	4
26	1671	10/27/67	1-A	15-1/2	Oct	102	8	1/2	Peel	20	8	PS	60	8
27	8046	12/18/67	1-A	15	Sq	102	4	1/2	Butt	20	8	NY	50	8
28	8385	2/29/68	1-A	15	Sq	102	4	1/2	Butt	20	8	NY	50	8

A

ALLUTE FLIGHT TEST SUMMARY

Suspension system						Inlet					
Meridian		Bridle	Bridle line	Riser	Swivel	Inlet					
Type	Strength (lb)	no. lines	strength (lb)	length (in.)	type	Springs	Size (in.)	Area (sq in.)	$\frac{W}{C_D A}$	Signal dropout	Remarks
NY	15	12	15	0	NB	12	10.5D	86	0.045	. . .	BALLUTE rupture
NY	15	12	15	0	NB	12	10.5D	86	. . .	. . .	BALLUTE rupture
NY	15	6	15	0	NB	6	19.5D	300	. . .	. . .	Payload separation
NY	15	6	15	0	NB	6	19.5D	300	. . .	. . .	Payload separation
NY	50	6	50	0	NB	6	19.5D	300	. . .	. . .	Payload separation
NY	50	6	50	0	NB	6	19.5D	300	. . .	. . .	Rupture at T + 11 min
NY	50	12	50	0	NB	12	12D	113	. . .	. . .	BALLUTE rupture
NY	50	12	50	0	NB	12	12D	113	. . .	. . .	BALLUTE rupture
NY	50	12	50	0	NB	12	10.5D	86	0.08	Moderate	Nominal
NY	50	12	50	0	NB	12	12.5	121	0.06	None	Nominal
NY	50	12	50	0	NB	12	12.5	121	0.05	Moderate	Nominal
NY	50	12	50	0	NB	12	12.5	121	0.05	Sparse	Nominal
NY	50	12	50	0	NB	12	12.5	121	0.05	Sparse	Nominal
NY	50	12	50	0	NB	12	12.5	121	0.05	Sparse	Nominal
NY	50	12	50	0	NB	12	12.5	121	0.05	Sparse	Nominal
NY	50	8	50	0	NB	8	9D	65	0.06	None	Nominal
NY	50	8	50	0	NB	8	9D	65	0.06	None	Nominal
NY	50	8	50	0	NB	8	9D	65	. . .	. . .	Payload separation
PS	60	8	50	0	NB	8	9D	65	. . .	. . .	Payload separation
NY	50	8	50	0	NB	8	9D	65	0.05	Periodic	Nominal
PS	60	8	50	0	NB	0	9D	65	0.05	Late	Nominal
PS	60	8	50	4	600	0	9D	65	0.045	Noise	Nominal
PS	60	8	50	4	600	0	9D	65	. . .	. . .	BALLUTE rupture
PS	60	8	50	9	600	0	9D	65	. . .	. . .	BALLUTE rupture
PS	60	4	50	6	600	0	24 × 24	576	. . .	. . .	Flat spin
PS	60	8	180	6	600	0	24D	452	0.045	Sparse	Nominal
NY	50	8	180	6	600	0	24 × 24	576	0.06	Periodic	Nominal
NY	50	8	180	24	300	0	22D	380	0.04	Moderate	Nominal

B

e. Configuration D

The primary purpose for the modification to the seventh and eighth units was to ascertain the adequacy of 1/3-mil Mylar. Because of the availability of 1/2-mil aluminized Mylar, this material was used in the three reflective panels and 1/3-mil clear Mylar constituted the remaining gores. The size of the BALLUTE was reduced from 16 ft across the flats of the hexagonal burble fence to 14 ft to avoid packaging problems. Breakup of both units dictated the immediate transition to 1/2-mil Mylar.

f. Configuration E

To reaffirm the structural integrity of 1/2-mil Mylar at the 12-1/2-ft BALLUTE size, a duplicate of the final configuration of the earlier contract was tested. This unit performed as expected with no signal dropouts on the TMQ-5 trace. The equilibrium descent velocity showed a W/C_DA of about 0.08 as opposed to the goal of 0.05. The development process from this point on was to increase the BALLUTE size for maximum drag area within the restraints of available packaging volume and to modify the geometry in order to increase C_D.

g. Configuration F

Units 10 through 13 were like Configuration E except for size which was 14 ft. Very little signal dropout occurred in any of the four flight tests. The ballistic coefficient ranged between 0.06 and 0.05. Although structurally sound and aerodynamically stable, the descent rate was still somewhat higher than the design goal established by the contract. The next obvious improvement was to increase the size to 15 ft.

h. Configuration G

Units 14 and 15 were simply scaled up to the 15-ft size, but in all respects were the same as Configuration F. Both flight tests reached the $W/C_DA = 0.05$ design goal.

i. Configuration H

In addition to the performance goals, the contract included a goal of a minimum cost configuration that had not been emphasized before in the upgrading of the configurations. Many of the changes from this point forward were designed primarily to reduce production costs. Two

economy measures were incorporated in Units 16 and 17. The number of gores was reduced from 12 to 8 and peel seams replaced butt seams to reduce seaming time. To enhance the descent rate, the frontal cone angle of the BALLUTE was changed from 80 to 102 deg. Once again, these units performed the mission without signal dropouts, but the W/C_DA inexplicably degraded to 0.06.

j. Configuration I

Because of the W/C_DA value of 0.06 for Configuration H, a further size increase was indicated. Units 18 through 21 had a 15-1/2-ft octagonal planform. As a further economy measure, Units 19 and 21 had 60-lb pressure sensitive glass reinforced tape for meridians while Units 18 and 20 retained the 50-lb woven nylon for their purpose.

Unit 18 experienced separation of the BALLUTE from the payload at ejection. No explanation of this failure has evolved nor has the failure occurred since. Unit 19 was deployed in an excessively high dynamic pressure because of low apogee and, therefore, must be categorized as no test. Unit 20 was the same configuration as Unit 18 and performed well with a $W/C_DA = 0.05$. Same periodic signal dropouts were recorded in the TMQ-5 chart. Unit 21 (same as Unit 19) repreated the $W/C_DA = 0.05$ performance, and no signal dropouts occurred.

k. Configuration J

Once again, cost saving modifications represented the major changes in Units 22 and 23. As a result of concurrent successful results in the elimination of the inlet erection springs for the Dartsonde BALLUTE, the same approach was tried on the Arcas BALLUTE. Unit 22 had a $W/C_DA = 0.045$, but Units 23 and 24 ruptured on deployment.

l. Configuration K

Configuration K represented a complete abandonment of the preceding Arcas configurations in preference to an exact scaling up of the square Loki-Dart BALLUTE. This 15-ft unit was assembled with butt seams and had a 2-sq-ft inlet. Test 25 apparently developed a burble fence tear and went into a flat spin some minutes after inflation. Unit 27 seemed to operate properly, but descended too fast with a $W/C_DA = 0.06$.

m. Configuration L

Configuration L was a duplicate of Configuration J except for the inlet, which was increased from a 9- to 24-in. diameter. Only sparse signal dropout occurred and the $W/C_DA = 0.045$.

n. Configuration M

To reduce inflation time, a Para-Inlet was incorporated in the 15-ft square BALLUTE. Goodyear Aerospace had been experimenting with this device as a means of rigidizing and stabilizing inflation inlets with ram-air pressure. The Para-Inlet is a type of annular parachute canopy placed in the inlet. This relatively small canopy inflates rapidly producing hoop tension in the adjacent BALLUTE film thereby maintaining a circular orifice for inflating the BALLUTE. The inflation time for Unit 28 was 6 sec as opposed to 38 sec required for inflation of Configuration K without Para-Inlet in Unit 27. The W/C_DA values of 0.04 and 0.045 were recorded. Moderate signal dropout was experienced. Motion pictures showed the BALLUTE to be extremely stable.

4. ARCAS BALLUTE FLIGHT TEST DATA

The complete outline of the details and results of each of the Arcas BALLUTEs tested under this phase of the contract are listed in Table I. All of the minute details of the BALLUTE construction and all of the performance intricacies are not tabulated. Only those characteristics which by their incorporation or deletion have had a significant effect on performance, structural integrity, or cost have been noted.

5. ARCAS BALLUTE PERFORMANCE SUMMARY

Many of the early configurations tested in the Arcas BALLUTE program reflected an effort to combine lightweight films (1/4- and 1/3-mil Mylar) with appropriate reinforcements to provide a structurally sound BALLUTE for this mission. As has been noted earlier, the loadings encountered at deployment cannot be accurately analyzed. For this reason every effort was made to ascertain by test that these lighter gage films do not provide an adequate structure for this BALLUTE.

Once it was determined that 1/2-mil Mylar was the appropriate film for

this size BALLUTE deployed under the dynamic conditions imposed by the Arcas mission, the structural failures ceased. Then a concentrated effort was conducted on geometric modifications to increase drag efficiency and gradual increases in size. Eventually the largest practicable BALLUTE with the most desirable drag and stability characteristics, which can be packaged in the space available in the current Arcas canister, was selected.

Unlike the Dart BALLUTE final configuration that was tested many times during the development effort, the final Arcas configuration coincided with the last flight test scheduled under this contract. Several additional flights of the model would have been desirable and should be considered for future efforts. A review of the manner in which the Arcas BALLUTE has met the design goals must be restricted to this one final unit (see Table II).

TABLE II - ARCASONDE BALLUTE PERFORMANCE

Performance characteristic	Design goal	Actual performance
Reliability (percent)	98	100
Stability (deg)	±3	±3
Ballistic coefficient, W/C_DA (lb/sq ft)	0.05	0.04
Reflectivity	Trackable by Mod-2, -589 radar	Tracked by Mod-2, FPS 16 radar
Unit production cost ($)	200	250

6. FINAL CONFIGURATION OF ARCAS BALLUTE

The BALLUTE configuration that evolved from the Arcas development program is shown in Figure 2. The planform is a 15-ft × 15-ft square that provides 225 sq ft of drag area for the deceleration mission. The main body of the BALLUTE forms a truncated 102-deg cone proceeding aft from the 3-ft diameter ram air inlet to a 10-3/4-ft square section at the burble fence. The fence itself extends out from the basic BALLUTE about 2-1/8 ft all around. The 3-ft-diameter ram-air opening is equipped with a Para-Inlet to speed up inflation time.

From the inlet opening forward, eight suspension lines of 50-lb break nylon strap converge at an O-ring attached to a 1/2-in.-wide, 6-in.-long nylon strap. The forward end of the nylon strap is attached to the aft ring of a 300-lb breakstrength ball bearing swivel. The swivel itself is rigidly fixed to the forward closure plate of the Arcas 1-A instrument. The material throughout the BALLUTE is 1/2-mil Mylar using butt seams throughout joined by 1/2-mil, 1/2-in.-wide Mylar tape. The only portion of this BALLUTE that is reflective is a 6-in.-wide band of the burble fence that is adjacent to the aft BALLUTE attachment station. Figures 2 through 7 show some of the significant details of various Arcas BALLUTE configurations fabricated during this program.

7. CONCLUSIONS AND RECOMMENDATIONS

The many flight tests conducted during this program and the evidence of the resultant data has reconfirmed the superiority of the BALLUTE as an extremely stable deployable decelerator. There is no evidence available that any parachute design can approach the BALLUTE performance with respect to reliability or stability in the altitude-velocity envelope of meteorological rocketsondes. The occurrence of structural failures in a relatively large number of the development program flight tests does not contradict these assertions.

The BALLUTE designs tested during this effort represent the most efficient aerodynamic drag configurations within the state of the art. The materials, panel arrangements, seam configurations, and fabrication techniques were chosen to provide the strongest pressure vessel structures for the least weight and volume penalties.

The greatest problem encountered during the Arcas BALLUTE development was not meeting the performance goals, but meeting the performance goals with a unit that could be packaged in a container designed for a parachute.

As a result of the data accumulated from the 29 Arcas BALLUTE flight tests the relationship between signal dropout and system stability is not perfectly clear.

Figure 2 - 15-Ft Square Arcas BALLUTE with 20-Percent Burble Fence

Figure 3 - Prepackaging Examination of 15-Ft Square Arcas BALLUTE

Figure 4 - Arcas BALLUTE Swivel and Bridle Assembly

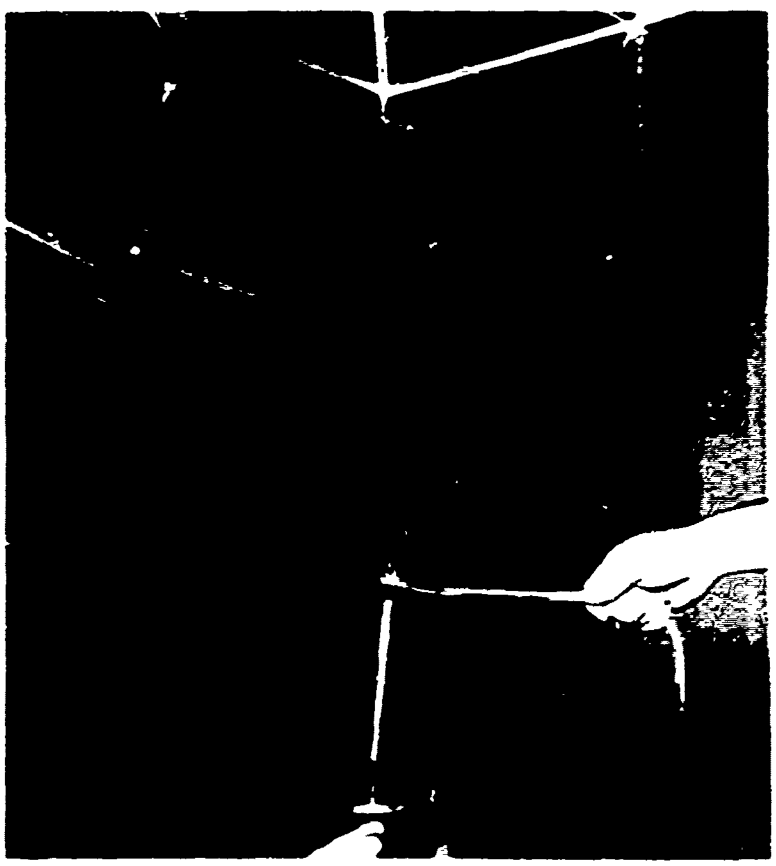


Figure 5 - Arcas BALLUTE Inlet and Suspension Systems

Figure 6 - Arcas BALLUTE Circular Inlet in Airstream

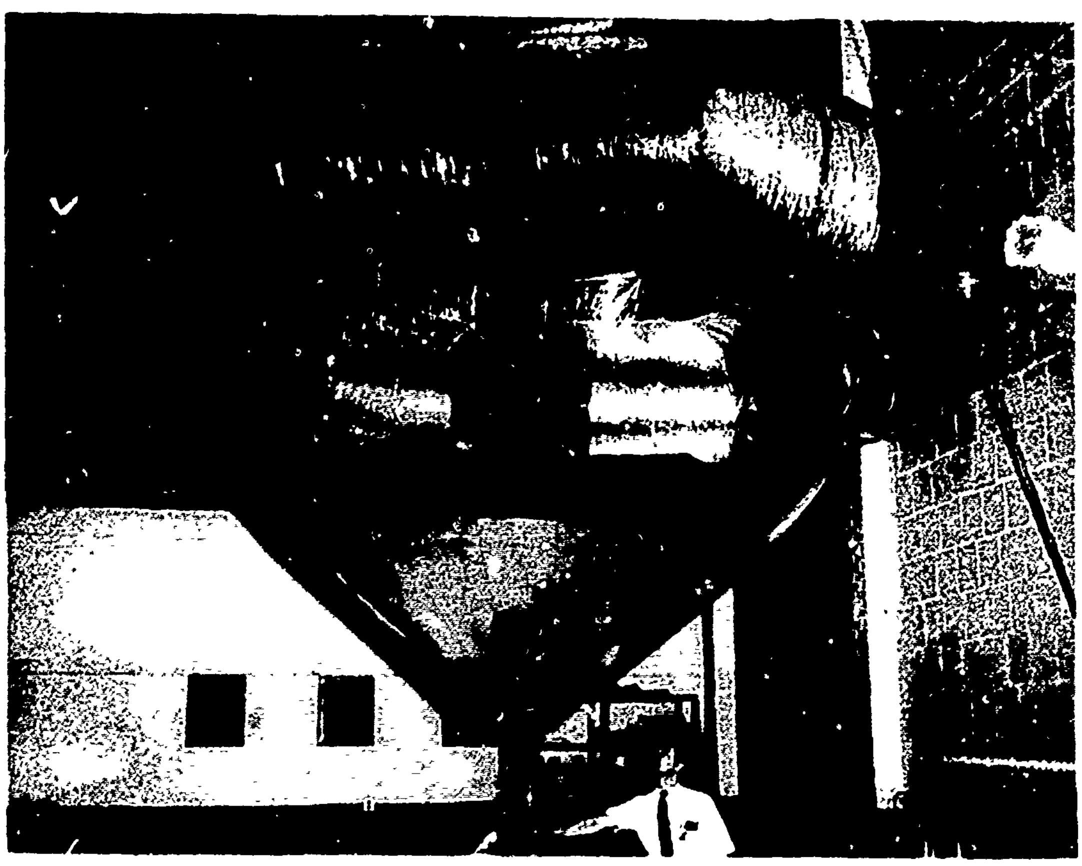


Figure 7 - 15-Ft Octagonal Arcas BALLUTE

This program resulted in a final BALLUTE configuration that may well provide the required stability, descent rate, reflectivity, and reliability if additional testing were to be conducted.

Goodyear Aerospace recommends that AFCRL consider the following items:

1. A comprehensive analysis of the cost and performance tradeoffs in increasing the BALLUTE canister volume
2. Additional testing of the final configuration resulting from this development effort
3. An investigation into improved methods for validating the compliance of test units with the performance criteria requested
4. An in-depth review of the Arcasonde 1-A data transmission antenna pattern and the causes of signal dropout

SECTION IV - LOKI-DART BALLUTE DEVELOPMENT

1. GENERAL

In contrast to the Arcas BALLUTE development program described in Section III, the fourth and final major configuration change to the Loki-Dart BALLUTE was achieved on the 17th of 25 developmental flight test units. The nine remaining tests of this configuration were conducted satisfactorily followed by submission and approval of fabrication drawings.

Fifty-five of these BALLUTEs then were fabricated and delivered to AFCRL for further evaluation. Based on the performance of the Dart BALLUTE during the development program supported by continuing good results obtained during the use of part of the 55 units mentioned, this BALLUTE (Parachute, Meteorological A/B28U-5) became an integral part of the recently standardized PWN-8B Meteorological Rocketsonde.

This rocketsonde system is currently in production and will be used to provide a portion of the soundings required by the Meteorological Rocket Network (MRN) during 1969.

2. DARTSONDE FLIGHT TEST SUMMARY

a. Group 1 (Configuration A)

The first two BALLUTEs tested had a cone angle of 80 deg with a 12-percent burble fence. The projected drag area was hexagonal, measuring six feet across the flats. The material for these units was 1/4-mil Mylar joined butt-seam fashion with 1/2-mil, 1/2-in.-wide heat-sealable Mylar tape. Three of the six main body gores were aluminized to provide radar reflectivity. The suspension system consisted of twelve 15-lb breaking strength woven nylon webs beginning at the aft pole of the BALLUTE and terminating in triplets at each of the four music wire springs that shaped the 10-1/2-in.-diameter inlet.

Premature separation of the instrument from the Dart body prior to apogee subjected the BALLUTE to extreme dynamic pressures and Unit 1 was destroyed. Dart Unit 2 deployed normally and decelerated the

system to an equilibrium $W/C_DA = 0.05$. No temperature data were acquired because of a thermistor failure.

b. Group 2 (Configuration A)

Because Configuration A yielded the desired ballistic coefficient, three more units of the same design were flown in the second group of Dart tests. Units 3 and 4 exhibited good drag characteristics with W/C_DA values between 0.04 and 0.045. The sparsity of signal dropouts on both tests was encouraging and indicated good aerodynamic stability. Unit 5 was connected to the BALLUTE by a two-line bridle that canted the instrument at a 45-deg angle. This unorthodox arrangement may have been the cause for BALLUTE rupture that occurred at deployment.

c. Group 3 (Configuration B)

In the interest of design simplification, Units 6 and 7 had only six meridians and the number of inlet erection springs was reduced from four to three. No separation of Unit 6 resulted in no test of the BALLUTE in that flight. Unit 7 performed well with a $W/C_DA = 0.04$ and moderate signal dropouts.

d. Group 4 (Configurations B and C)

The fourth group of BALLUTEs consisted of one 6-ft hexagonal unit (Unit 9) that was carried over from the last series and two new 6-1/2-ft square BALLUTEs designed to increase the drag area and reduce the number of gores and, therefore, the fabrication time of the units. The frontal cone angle on this new square BALLUTE was 102 deg instead of 80 deg, and the burble fence diameter was 20 percent of the basic BALLUTE diameter instead of 12 percent. This new configuration was drop tested in the Goodyear Aerospace airdock prior to flight testing. No data were obtained for Units 8, 9, and 10 because of a recurrence of the separation problem on the Loki-Dart system.

e. Group 5 (Configurations B and C)

The next logical step was to repeat the configurations of Group 4 in Group 5. Two square BALLUTEs (Units 11 and 13) and two hexagonal BALLUTEs (Units 12 and 14) were built for this series.

Once again separation failure claimed one of the four test items (Unit 14). The remaining two square units and the one hexagonal unit all yielded $W/C_DA = 0.04$ and sparse signal dropout. Because of the success of the square configuration and in view of the potential cost savings in this greatly simplified design, the remainder of the program consisted of improving this basic design.

f. Group 6 (Configuration C)

To reconfirm the performance of this configuration, two more units were built with a design modification on one of these. A film skirt fairing was added to the BALLUTE forward of the burble fence, extending from the main body at about 45 deg and terminating tangentially on the burble fence. This modification was an effort to change the pressure distribution in this area and increase the drag coefficient. The opposite, however, occurred and the W/C_DA for the modified unit (Unit 15) was about 0.05. Unit 16 performed as before.

g. Group 7 (Configuration D)

It was apparent at this point that a further increase of size could be accomplished within the restraints of available packing volume. The remaining units, 17 through 25, were all 7-ft square BALLUTEs. The elimination of the inlet erection springs and the transition to peel seams further simplified construction. The performance of these last nine units is recorded in Table III.

The nominal W/C_DA value for the Loki-Dart system with the 7-ft square BALLUTE is 0.03. Malfunction of the separation system on the launch pad negated any data from Units 20 and 22.

3. DARTSONDE FLIGHT TEST DATA

While the information in Table III is not presented in its raw form and reflects some first order reduction and interpretation, it does include the significant physical characteristics of each unit as well as the pertinent performance data. The original data from which the table is derived are:

1. TMQ-5 temperature oscillograph trace
2. Meteorological rocket data log sheet
3. Plot board tracing of one or more tracking radar

TABLE III - LOKI-DART FLIGHT TEST SUMMARY

Group	Configuration number	Unit number	Test number	Test date	Instrument	BALLUTE construction: Diam or width (ft)	Shape	Cone angle (deg)	Number gores	Film gage (mil)	Type seam	Burble fence size (%)	Meridian number	Meridian type	Meridian strength (lb)	Suspension system: Bridle (number lines)	Bridle line strength (lb)	Riser length	Swivel type	Spring	S(
1	A	1	2382	4-20-66	Data	6.0	Hex	80	12	1/4	Butt	12.5	12	Woven nylon	15	12	15	Standard Dart cable	Machined magnesium wear plate	4	10
	A	2	3084	4-22-66	Data	6.0	Hex	80	12	1/4	Butt	12.5	12	Woven nylon	15	12	15	Standard Dart cable	Machined magnesium wear plate	4	10
2	A	3	2643	5-24-66	Data	6.0	Hex	80	12	1/4	Butt	12.5	12	Woven nylon	15	12	15	Standard Dart cable	Machined magnesium wear plate	4	10
	A	4	2561	5-26-66	Metro	6.0	Hex	80	12	1/4	Butt	12.5	12	Woven nylon	15	12	15	Standard Dart cable	Machined magnesium wear plate	4	10
	A	5	2793	5-27-66	Metro	6.0	Hex	80	12	1/4	Butt	12.5	12	Woven nylon	15	12	15	Standard Dart cable	Machined magnesium wear plate	4	10
3	B	6	7255	7-6-66	Data	6.0	Hex	80	6	1/4	Butt	12.5	6	Woven nylon	15	6	15	Standard Dart cable	Machined magnesium wear plate	3	13
	B	7	0906	7-6-66	Metro	6.0	Hex	80	6	1/4	Butt	15.5	6	Woven nylon	15	6	15	Standard Dart cable	Machined magnesium wear plate	3	13
4	C	8	1795	9-21-66	Data	6.5	Sq	102	4	1/4	Butt	20.0	4	Woven nylon	15	4	15	Standard Dart cable	Machined magnesium wear plate	4	11
	B	9	3768	9-21-66	Data	6.0	Hex	80	6	1/4	Peel	12.5	6	Woven nylon	15	6	15	Standard Dart cable	Machined magnesium wear plate	3	13
	C	10	1734	9-22-66	Data	6.5	Sq	102	4	1/4	Butt	20.0	4	Woven nylon	15	4	15	Standard Dart cable	Machined magnesium wear plate	4	11
5	C	11	4765	11-14-66	Data	6.5	Sq	102	4	1/4	Butt	20.0	4	Woven nylon	15	4	15	Standard Dart cable	Machined magnesium wear plate	4	11
	B	12	3166	11-14-66	Data	6.0	Hex	80	6	1/4	Peel	12.5	6	Woven nylon	15	6	15	Standard Dart cable	Machined magnesium wear plate	3	13D
	C	13	6258	11-15-66	Data	6.5	Sq	102	4	1/4	Butt	20.0	4	Woven nylon	15	4	15	Standard Dart cable	Machined magnesium wear plate	4	11
	B	14	6815	11-15-66	Data	6.0	Hex	80	6	1/4	Peel	12.5	6	Woven nylon	15	6	15	Standard Dart cable	Machined magnesium wear plate	3	13D
6	C	15	0015	1-30-67	Data	6.5	Sq	102	4	1/4	Butt	20.0	4	Woven nylon	15	4	15	Standard Dart cable	Machined magnesium wear plate	4	11
	C	16	0099	1-31-67	Data	6.5	Sq	102	4	1/4	Peel	20.0	4	Woven nylon	15	4	15	Standard Dart cable	Machined magnesium wear plate	4	11
7	D	17	1616	2-27-67	Data	7.0	Sq	102	4	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	Machined magnesium wear plate	4	11
	D	18	0613	2-28-67	Data	7.0	Sq	102	4	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	Machined magnesium wear plate	4	11 ×
	D	19	4893	4-11-67	Data	7.0	Sq	102	4	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 ×
	D	20	3600	4-12-67	Data	7.0	Sq	102	4	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 ×
	D	21	5395	5-9-67	Data	7.0	Sq	102	4	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 ×
	D	22	9480	5-9-67	Data	7.0	Sq	102	4	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 ×
	D	23	8767	5-12-67	Data	7.0	Sq	102	4	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 ×
	D	24	6513	5-12-67	Data	7.0	Sq	102	4	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 ×
	D	25	8534	5-18-67	Data	7.0	Sq	102	4	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 ×

A

...III - LOKI-DART FLIGHT TEST SUMMARY

...n- ...r ...es	BALLUTE construction: Film gage (mil)	Type seam	Burble fence size (%)	Meridian number	Meridian type	Meridian strength (lb)	Suspension system: Bridle (number lines)	Bridle line strength (lb)	Riser length	Swivel type	Inlet: Spring	Size (in.)	Area (sq in.)	Unit no.	$\frac{W}{C_D A}$	Signal drop-out	Remarks
	1/4	Butt	12.5	12	Woven nylon	15	12	15	Standard Dart cable	Machined magnesium wear plate	4	10.5D	86	1	. . .	. . .	Premature separation
	1/4	Butt	12.5	12	Woven nylon	15	12	15	Standard Dart cable	Machined magnesium wear plate	4	10.5D	86	2	0.050	. . .	Thermistor failure
	1/4	Butt	12.5	12	Woven nylon	15	12	15	Standard Dart cable	Machined magnesium wear plate	4	10.5D	86	3	0.045	Moderate	Nominal
	1/4	Butt	12.5	12	Woven nylon	15	12	15	Standard Dart cable	Machined magnesium wear plate	4	10.5D	86	4	0.04	After T + 11	Nominal
	1/4	Butt	12.5	12	Woven nylon	15	12	15	Standard Dart cable	Machined magnesium wear plate	4	10.5D	86	5	. . .	. . .	BALLUTE rupture
	1/4	Butt	12.5	6	Woven nylon	15	6	15	Standard Dart cable	Machined magnesium wear plate	3	13D	130	6	. . .	. . .	No separation
	1/4	Butt	15.5	6	Woven nylon	15	6	15	Standard Dart cable	Machined magnesium wear plate	3	13D	130	7	0.040	None	Nominal
	1/4	Butt	20.0	4	Woven nylon	15	4	15	Standard Dart cable	Machined magnesium wear plate	4	11 × 11	123	8	. . .	. . .	No separation
	1/4	Peel	12.5	6	Woven nylon	15	6	15	Standard Dart cable	Machined magnesium wear plate	3	13D	130	9	. . .	. . .	No separation
	1/4	Butt	20.0	4	Woven nylon	15	4	15	Standard Dart cable	Machined magnesium wear plate	4	11 × 11	123	10	. . .	. . .	No separation
	1/4	Butt	20.0	4	Woven nylon	15	4	15	Standard Dart cable	Machined magnesium wear plate	4	11 × 11	123	11	0.040	Late	Nominal
	1/4	Peel	12.5	6	Woven nylon	15	6	15	Standard Dart cable	Machined magnesium wear plate	3	13D	130	12	0.040	Moderate	Nominal
	1/4	Butt	20.0	4	Woven nylon	15	4	15	Standard Dart cable	Machined magnesium wear plate	4	11 × 11	123	13	0.040	Late	Nominal
	1/4	Peel	12.5	6	Woven nylon	15	6	15	Standard Dart cable	Machined magnesium wear plate	3	13D	130	14	. . .	. . .	No separation
	1/4	Butt	20.0	4	Woven nylon	15	4	15	Standard Dart cable	Machined magnesium wear plate	4	11 × 11	123	15	0.050	None	Nominal
	1/4	Peel	20.0	4	Woven nylon	15	4	15	Standard Dart cable	Machined magnesium wear plate	4	11 × 11	123	16	0.040	None	Nominal
	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	Machined magnesium wear plate	4	11 × 11	123	17	0.030	Noise	Nominal
	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	Machined magnesium wear plate	4	11 × 11	123	18	0.040	None	Nominal
	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 × 11	123	19	0.030	None	Nominal
	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 × 11	123	20	. . .	. . .	Separation on pad
	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 × 11	123	21	0.040	Random	Nominal
	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 × 11	123	22	. . .	. . .	Separation in pad
	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 × 11	123	23	0.030	Sparse	Nominal
	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 × 11	123	24	0.030	Sparse	Nominal
	1/4	Peel	20.0	4	Glass tape	25	4	15	Standard Dart cable	40-lb ball bearing	0	11 × 11	123	25	0.030	Moderate	Nominal

B

4. Motion picture film from ground-based camera
5. Digital printouts of smoothed or unsmoothed radar data
6. Sonde motion, wind, and density data as computed by the University of Dayton

4. FINAL CONFIGURATION OF DART BALLUTE

Goodyear Aerospace Drawing 545A500-001-101 for Parachute, Meteorological A/B28U-5 describes the final Loki-Dart BALLUTE in full detail.

The BALLUTE is a square that is seven feet on each side when measured at the burble fence extremities. The included angle of the conical forward section is 102 deg at the ram-air inlet that is 11-in. square.

All of the basic film material is 1/4-mil Mylar and the burble fence gores are aluminized. The gores have been assembled with peel seams 1/10-in. wide of 2-1/2-mil heat-sealable thermoplastic tape. The inlet opening is reinforced with 1/2-in.-wide 1/2-mil Mylar tape. Four 50-lb breaking-strength nylon cords constitute the bridle suspension between the inlet and swivel assembly. The spring snap catch at the lower end of the swivel assembly provides the attachment interface with the instrument suspension cable. Figures 8 through 13 show some of the features of the Dart BALLUTE system.

5. DART EVALUATION UNITS

Fifty-five units of the final configuration were fabricated and shipped to AFCRL for further evaluation. The Goodyear Aerospace program did not include any data anlysis nor performance evaluation of these units.

A number of these units were removed from the staves and examined after several months of storage, and the Mylar film was found to be adhering to the edges of the meridian strap tapes. These meridian tapes are made of 1-mil Mylar with fiberglass filament imbedded in the pressure sensitive adhesive. The adhesive is about 7 mil thick and apparently had been forced out along the edge of the tape from the prolonged storage at the high pressures of the dense package. This sticking of the material could result in tears and deployment and aborting of the mission. The

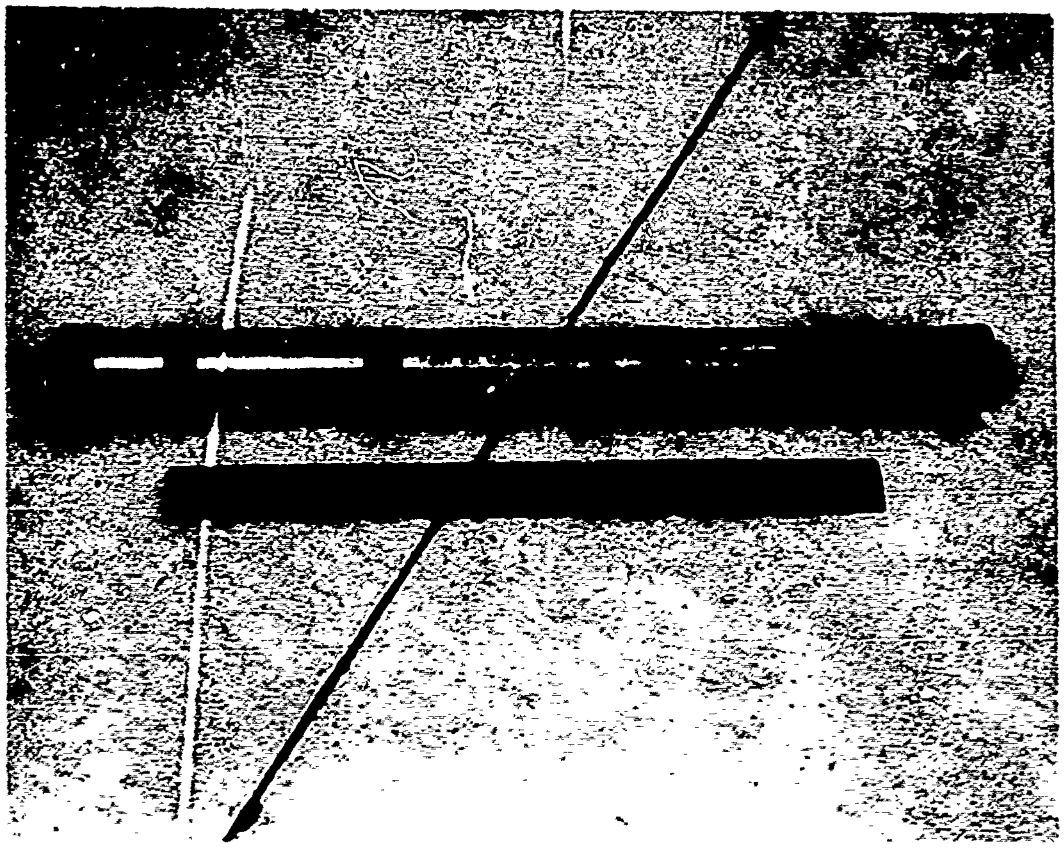


Figure 8 - Loki-Dart BALLUTE Packaged in Staves

Figure 9 - Configuration Check of the First Square
Loki-Dart BALLUTE

Figure 10 - Loki-Dart BALLUTE Swivel Assembly and Suspension System

Figure 11 - Folding the Loki-Dart BALLUTE

Figure 12 - Profile of the 7-Ft Square Loki-Dart BALLUTE

Figure 13 - Aft View of 7-Ft Square
Loki-Dart BALLUTE

problem was solved by replacing the pressure sensitive meridians with heat-sealable 1/2-mil Mylar tapes on the fabrication drawings.

6. DARTSONDE BALLUTE PERFORMANCE SUMMARY

Table IV shows the degree of success of the development program in achieving the design goals and the actual performance characteristics of the final configuration, which was the 7-ft square BALLUTE.

Because of the relatively few configurations tried during this development effort, Table V has been generated to show the results of the 25 development flight tests at AFETR and the 2 tests conducted at Vandenberg AFB under a separate effort. Table V is self-explanatory and covers the major performance characteristics of the system. There were no failures in any of the 18 flights where proper deployment conditions were achieved. Drag efficiency is expressed in terms of square feet of effective drag area per pound of BALLUTE and illustrates the main reason for the selection of the 7-ft square design as the final configuration for this program.

A detailed analysis of the performance of the BALLUTEs tested during this program has been conducted by the University of Dayton Research Institute and the initial findings have been published in AFCRL-67-0659, The BALLUTE: A Retardation Device and Wind Sensor.

TABLE IV - DARTSONDE BALLUTE PERFORMANCE

Performance characteristics	Design goal	Actual performance
Reliability (percent)	98	100
Stability (deg)	±3	±3
Ballistic coefficient, W/C_DA (lb/sq ft)	0.05	0.03
Reflectivity	Trackable by Mod-2, -589	Tracked by Mod-2, FPS 16, FPQ 18
Production unit cost ($)	30	125

7. CONCLUSIONS AND RECOMMENDATIONS

Since the Dart BALLUTE system has met most of the technical design goals, Goodyear Aerospace recommends that the BALLUTE as currently configured be adapted as the standard stabilizing decelerator for all Loki-Dart and Judi-Dart meteorological rocketsondes. The additional cost of the BALLUTE over parachute may be justified by greatly improved performance.

Goodyear Aerospace further recommends that the Dart BALLUTE be used for providing a stable platform for the transponder Dart system during its development to maintain continuous ranging capability through proper orientation of transmitting and receiving antennas.

Although the reflectivity requirement specified by the contract was related only to radar trackability, the Dart instrument manufacturer has indicated that the metalized surfaces of the trailing decelerator play a significant role in reflecting the 1680-kHz signal from the inverted monopole antenna. Further study of the geometry of the reflective surfaces and the distribution of the reflectivity in light of this secondary function appears to be in order.

Since BALLUTEs of film construction have been successfully deployed above 300,000 ft, further work concurrent with sensor antenna and system development should be pursued in anticipation of higher altitude meteorological soundings.

TABLE V - LOKI-DART BALLUTE PERFORMANCE SUMMARY*

Configuration	Test no.	W/C_DA (psf)	Signal dropout	Swivel	No. of springs	C_D
6-ft-hexagonal, 80-deg cone; 12-1/2 percent fence	3084	0.04 - 0.05	None	Magnetic assembly	4	0.85 -
	2643	0.04	At high	Magnetic assembly	4	0.85
	2561	0.04	Few	Magnetic assembly	4	0.85
	0906	0.04	1st 13 min	Magnetic assembly	3	0.85
	3166	0.04	Some	Magnetic assembly	3	0.85
6-1/2-ft-square, 102-deg cone; 20 percent fence	4765	0.035 - 0.04	None	Magnetic assembly	4	0.77 -
	6258	0.035 - 0.04	None	Magnetic assembly	4	0.77 -
	099	0.04	None	Magnetic assembly	4	0.67
	0015	0.045	None	Magnetic assembly	4	0.63
7-ft-square, 102-deg cone; 20 percent fence	1616	0.03	None	Magnetic assembly	4	0.76
	4893	0.03	None	Sampo	None	0.74
	8767	0.03	1st 9 min	Sampo	None	0.74
	6513	0.03	1st 7 min	Sampo	None	0.74
	8534	0.03	1st 8 min	Sampo	None	0.74
	0577	0.03	None	Sampo	None	0.74
	3995	0.03	None	Sampo	None	0.74
	0613	0.04	None	Magnetic assembly	4	0.57
	5395	0.04	1st 4 min	Sampo	None	0.56

*Twenty-seven Loki-Dart BALLUTEs were flight tested during this program. Eighteen flights tests of the BALLUTEs. In 9 of the 27 flights the test point was not achieved due to separatio Dart system and were categorized as "no test." No failures were encountered. The 18 good in this table include 16 flights conducted at AFETR and 2 flights conducted under a separate e

+The unit numbers in this column are the same as the unit numbers in Table III.

A

I-DART BALLUTE PERFORMANCE SUMMARY*

Signal ropout	Swivel	No. of springs	C_D	$C_D A/W_B$ (sq ft/lb)	Unit+ no.
ne	Magnetic assembly	4	0.85 - 0.68	91 - 73	2
high	Magnetic assembly	4	0.85	91	3
w	Magnetic assembly	4	0.85	91	4
t 13 min	Magnetic assembly	3	0.85	91	7
me	Magnetic assembly	3	0.85	91	12
ne	Magnetic assembly	4	0.77 - 0.67	90 - 78	11
ne	Magnetic assembly	4	0.77 - 0.67	92	13
ne	Magnetic assembly	4	0.67	91	16
ne	Magnetic assembly	4	0.63	64	15
ne	Magnetic assembly	4	0.76	106	17
ne	Sampo	None	0.74	113	19
t 9 min	Sampo	None	0.74	113	23
t 7 min	Sampo	None	0.74	113	24
t 8 min	Sampo	None	0.74	113	25
ne	Sampo	None	0.74	113	V
ne	Sampo	None	0.74	113	V
ne	Magnetic assembly	4	0.57	80	18
t 4 min	Sampo	None	0.56	86	21

light tested during this program. Eighteen flights were considered valid ts the test point was not achieved due to separation problems in the Loki- st." No failures were encountered. The 18 good flight tests summarized AFETR and 2 flights conducted under a separate effort at Vandenberg AFB.

e as the unit numbers in Table III.

B

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13. ABSTRACT
Goodyear Aerospace Corporation completed a program to develop a stabilizing decelerator for the Arcas and Loki-Dart meteorological rocketsondes. During the program of cyclic modification, test, and evaluation, 53 development units were flight tested at the Air Force Eastern Test Range. The design performance goals were reached for both systems. Fifty-five preproduction units of the Loki-Dart BALLUTE were fabricated for further evaluation by Air Force Cambridge Research Laboratories. As a result of this program the Loki-Dart BALLUTE (Parachute, Meteorological A/B28U-5) was incorporated in the standardized PWN-8B Meteorological Rocketsonde currently in production.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
BALLUTE (BALLoon-parachUTE)						
Arcas rocket						
Retardation device						
Parachute						
Deceleration						
Stabilization						
Recovery						
Rocketsonde						
Radiosonde						
Meteorology						
Meteorological sounding						
Meteorological instruments						
Loki-Dart						

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